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Research Article

# Radiolysis-induced Dosimetric Characterization of Aqueous Solutions of a Synthetic Dye for Gamma Dosimetry

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**Abstract:** In this study, radiolysis-induced dosimetric response of the alkaline aqueous solutions of Sandalfix Orange C2RL (SO) dye was studied spectrophotometrically. Absorption peak ($\lambda_{max}$) was determined by using a UV/VIS spectrophotometer. Absorbance (A) of the irradiated and un-irradiated sample solutions was measured at this $\lambda_{max}$. $Cs^{137}$ gamma radiation source was utilized for the irradiation of the sample solutions within 0.1-1 kGy and 10-100 kGy dose ranges, i.e., low and high dosimetry, respectively. The absorbance (A) of the sample solutions followed linearly and logarithmically decreasing functions with respect to absorbed dose (D) for low and high dosimetry, respectively. The % discoloration of the sample solutions was found to be increased exponentially with respect to absorbed dose (D) within low dosimetry; while logarithmic increase in %Đ was observed for high dosimetry.

**Keywords:** Gamma radiation, dosimetry, color, reactive range 122, absorbance

## 1. INTRODUCTION

Now-a-days the chances of exposure to ionizing radiation have been increased; Ionizing Radiations (IRs) are capable to produce ions in the subjected substance(s) and cause structural changes into the exposed material(s). The process of calculating the quantity of absorbed dose of IRs is called Radiation Dosimetry (RD). Radiation processing is being controlled by RD; and therefore, is an active search area for scientists. There are many types of dosimeters i.e., thermo-luminescent detectors (TLDs), ionizing chamber dosimeter (IC), fricke dosimeter, film dosimeter and dye dosimeter etc. Chemical dosimeters respond linearly, logarithmically or exponentially etc. upon irradiation (*working principal*) under appropriate conditions [1]. The absorbance (A) of acidic aqueous solutions of Sandalfix Orange C2RL (SO) followed a linearly decreasing function with respect to absorbed dose (D) within low dosimetry range; while logarithmic decrease in absorbance (A) of sample solutions was observed for high dosimetry range [1-2]. Synthetic dyes contain chemicals and have also been used for dosimetric purposes in many forms like aqueous solutions [3-5] and polyvinyl alcoholic films [6-8] etc. In the aqueous solution, irradiation can cause the production of hydrated electron, $H_2O_2$, $H_2$, $OH^-$, $H^+$ and •OH radical; this formation depends upon the linear energy transfer value of radiation [9]. Researchers have used different colors, i.e., direct yellow 12 [9], alizarin yellow GG [10], 2, 6 dinitro phenol [11] and methyl violet 6B [12], etc. The γ-ray interaction with the dye solutions caused the enhancement of number of $H^+$ ions in the solutions; resulting an increase in acidity of the sample solutions [5]. Selected dye is relatively cheap and easily available in market. The objective of this study is to check the radiolysis-induced dosimetric response of alkaline aqueous solutions of Sandalfix Orange C2RL (SO) dye within the selected gamma dose range, respectively.

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## 2. MATERIALS AND METHODS

### 2.1. Pre-irradiation Treatments

SO (Molecular Formula: $C_{31}H_{20}ClN_7Na_4O_{16}S_5$) dye was collected from *Sandal Dyestuff Industries Pvt. Ltd. Faisalabad, Pakistan*; and was used without further purification. 0.5 gram (weighted by Mettler H35AR (USA) balance) of SO dye was dissolved in one liter of deionized water (electrical conductivity less than 1 µSiemens/cm) collected from *Pakistan Scientific Traders, Faisalabad, Pakistan,* to prepare the aqueous solutions of the dye. The pH of sample solutions was measured by pH meter (Hanna HI 83141); and controlled by using one molar solution of NaOH and HCl, respectively [13]. Sample solutions having pH 8, 9 and 10 were prepared. The prepared solutions were kept in *black box* to avoid the unwanted absorbance of light. A UV-VIS spectrophotometer (Lambda 25 1.27, Perkin Elmer, USA) was utilized for the measurement of absorption peak ($\lambda_{max}$) and absorbance (A) of all sample solutions was calculated at this $\lambda_{max}$ [10]. Cuvettes (path length of 10 mm) were used to keep the solutions in the object beam.

### 2.2. Post-irradiation Treatments

Gamma radiation source ($Cs^{137}$ with dose rate of 660 Gy/h) available at *Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad, Pakistan,* was utilized for irradiation of the sample solutions. Glass ampoules (internal diameter = 1.03 cm and thickness = 0.18 cm) with fit in ground stopper were used to keep the solutions in gamma radiation source for predetermined interval of time. The irradiation process was categorized in two different phases, i.e., 0.1-1 kGy (low dosimetry) and 10-100 kGy (high dosimetry), respectively. Figure 1 illustrates the molecular structure of SO dye.

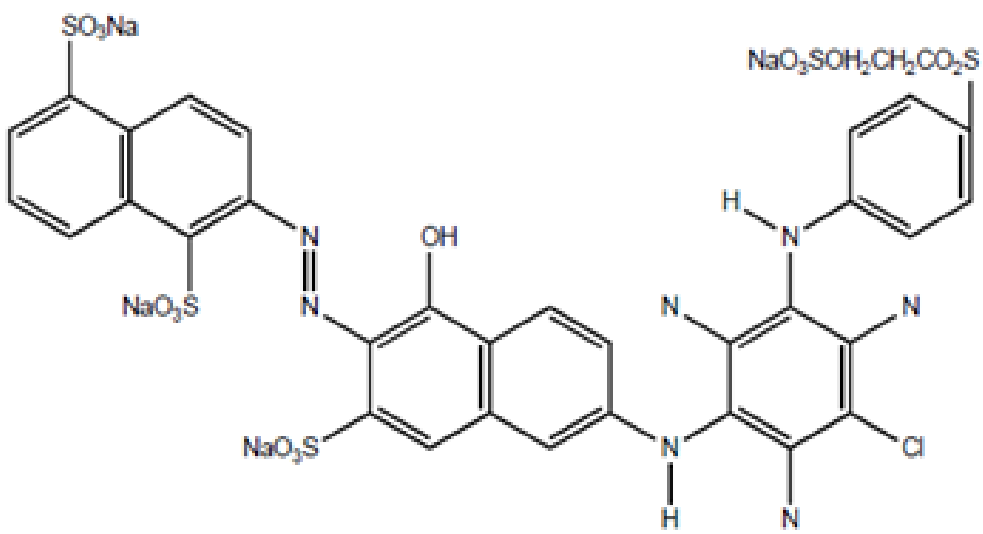


**Fig. 1.** Molecular structure of SO dye.

## 3. RESULTS AND DISCUSSION

The response curves were plotted for absorbance (A) versus absorbed dose (D) and % discoloration against absorbed dose (D) for the sample solutions of SO dye.

$$A_8 = -0.0008 \times D + 2.8232 \qquad R^2 = 0.4 \qquad (1)$$

$$A_9 = -0.0006 \times D + 2.7407 \qquad R^2 = 0.4 \qquad (2)$$

$$A_{10} = -0.0006 \times D + 2.8295 \qquad R^2 = 0.3 \qquad (3)$$

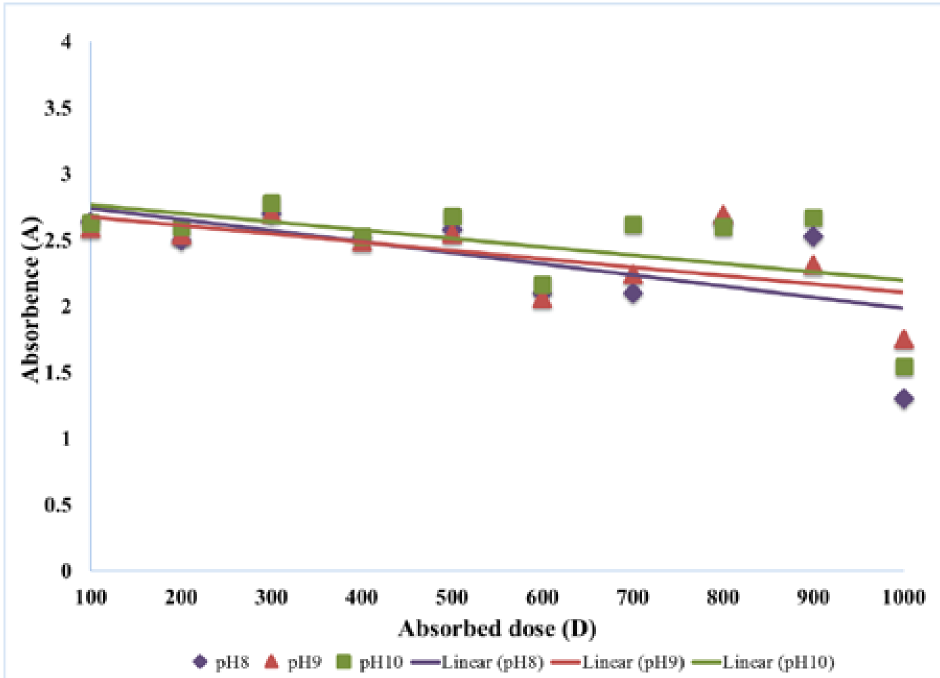


**Fig. 2.** Absorbance of SO dye dose for low dosimetry.

Where, $A_8$, $A_9$ and $A_{10}$ represent the absorbance (A) of the sample solutions having pH 8, 9 and 10, respectively. Equations 1-3 show the regression models along with correlation coefficients ($R^2$) for the absorbance (A) versus absorbed dose (D) within low dosimerty range. The absorbance (A) of sample solutions follows a linearly decreasing function with respect to absorbed dose (D) within low dosimetry.

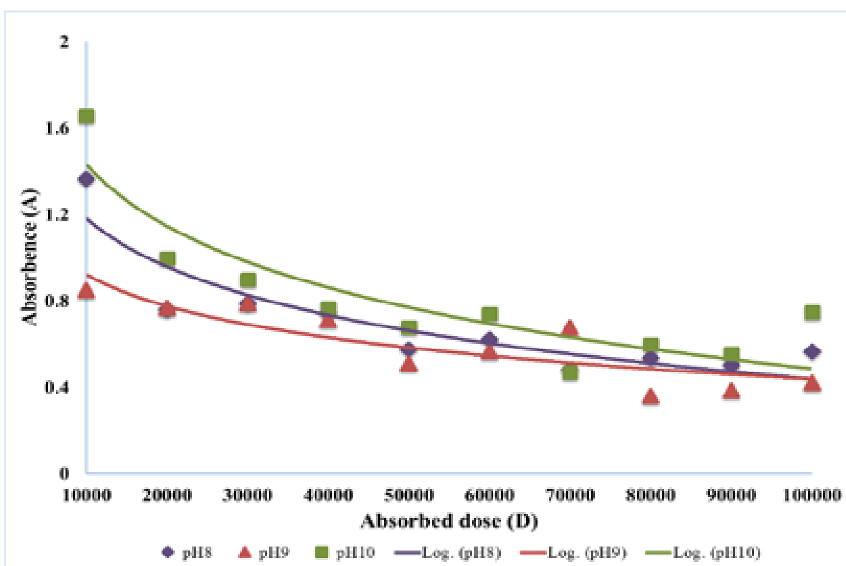


**Fig. 3.** Absorbance of SO dye versus absorbed dose for high dosimetry.

$$A_8 = -0.323 \times \ln(D) + 4.1547 \qquad R^2 = 0.8 \qquad (4)$$

$$A_9 = -0.21 \times \ln(D) + 2.8577 \qquad R^2 = 0.7 \qquad (5)$$

$$A_{10} = -0.411 \times \ln(D) + 5.2124 \qquad R^2 = 0.8 \qquad (6)$$

Where, $A_8$, $A_9$ and $A_{10}$ show the absorbance (A) of the sample solutions having pH 8, 9 & 10, respectively. Equations 4-6 show the regression models along with $R^2$. The absorbance (A) of the sample solutions of SO dye decreases logarithmically with respect to absorbed dose (D) within high dosimetry range.

The % discoloration of the aqueous solutions of SO dye can be calculated in terms of absorbance (A) of the sample solutions at pre and post irradiations stages as given in equation 7 [3,10].

$$\%Đ = [(A_{\circ} - A_i)/ A_{\circ}] \times 100 \qquad (7)$$

Where, $A_{\circ}$ is the absorbance of the pre-irradiated sample solutions and "$A_i$" is the absorbance of the post-irradiated sample solutions.

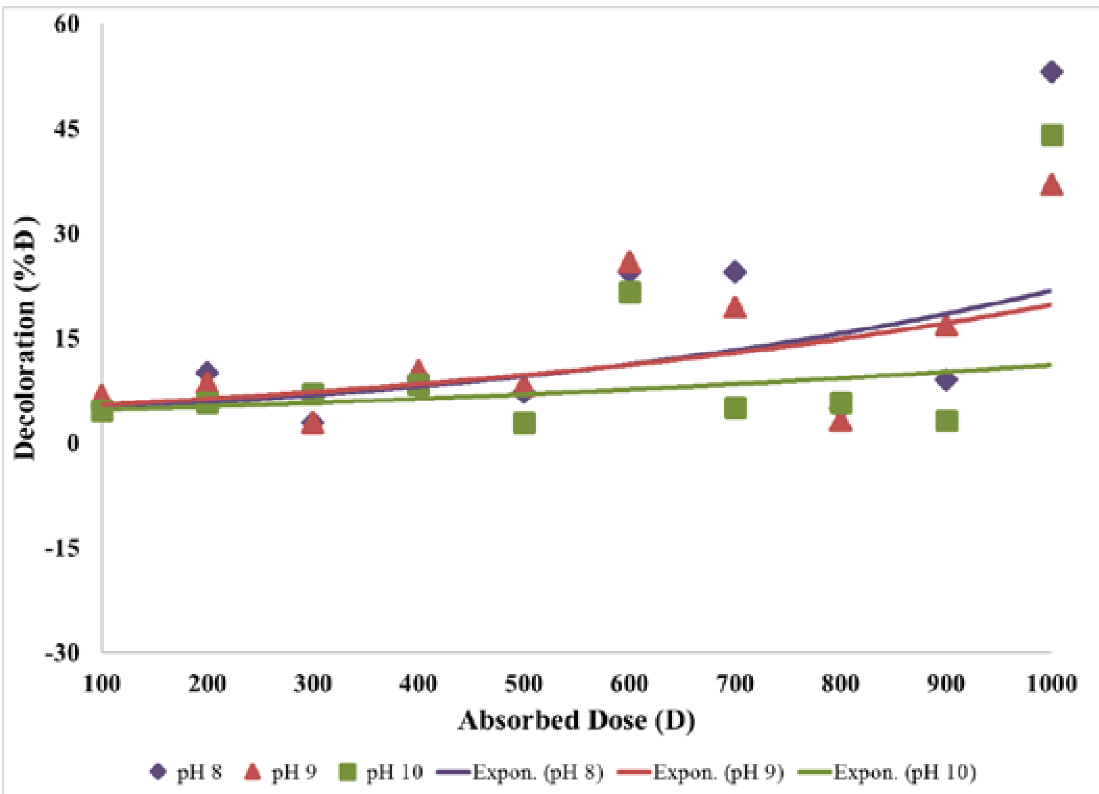


**Fig. 4.** Discoloration of SO dye versus absorbed dose for low dosimetry.

$$\%Đ_8 = 4.1652 \times e^{0.0017\times D} \qquad (8)$$

$$\%Đ_9 = 4.7543 \times {}^{0.0014\times D} \qquad (9)$$

$$\%Đ_{10} = 4.3313 \times e^{0.0009\times D} \qquad (10)$$

Where, $\%Đ_8$, $\%Đ_9$ and $\%Đ_{10}$ represent the % discoloration (%Đ) of the samples having pH 8, 9 and 10, respectively. Equations 8-10 show the regression models for low dosimetry. The %Đ is found to increase exponentially with respect to absorbed dose (D) within low dsosimetry.

$$\%Đ_8 = 11.612 \times \ln(D) - 49.449 \qquad R^2 = 0.8 \qquad (11)$$

$$\%Đ_9 = 7.5617 \times \ln(D) - 2.7936 \qquad R^2 = 0.7 \qquad (12)$$

$$\%Đ_{10} = 14.877 \times \ln(D) - 88.855 \qquad R^2 = 0.8 \qquad (13)$$

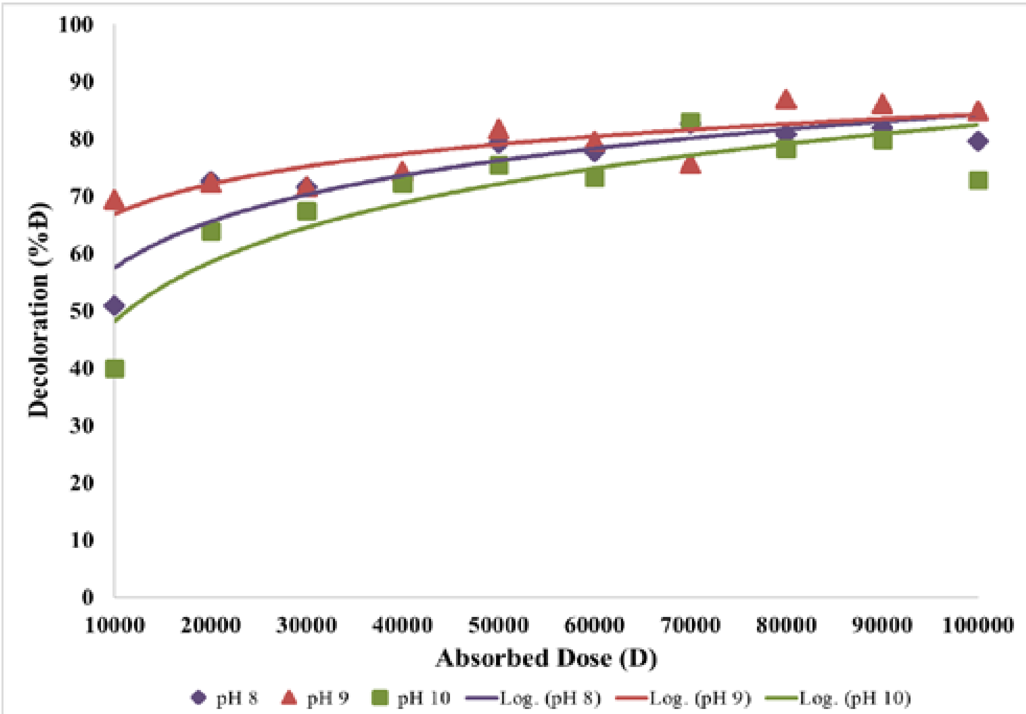


**Fig. 5.** Discoloration of SO dye versus absorbed dose for high dosimetry.

The % decoloration of the sample solutions having pH 8, 9 and 10 is indicated by $\%Đ_8$, $\%Đ_9$ and $\%Đ_{10}$, respectively. Equations 11-13 show the regression models along with $R^2$ values and explain the logarithmic increase in %Đ with respect to absorbed dose (D) within high dosimetry.

## 4. CONCOLUSIONS

The absorbance (A) of the alkaline aqueous solutions of *Sandalfix Orange C2RL* (SO) dye follows a linearly decreasing function against absorbed dose (D) for low dosimetry while logarithmic decrease in absorbance (A) of the sample solutions is observed within high dosimetry range. The % decoloration of the sample solutions was increased exponentially and logarithmically with respect to absorbed dose (D) for low and high dosimetry, respectively. The alkaline sample solutions of SO dye exhibited a good dosimetric response upon irradiation within the selected dose ranges. However, additional studies are warranted to check the response of SO dye within intermediate dosimetry, i.e., 1-10 kGy.

## 5. ACKNOWLEDGEMENTS

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